Designing for Aquatic Organism Passage at Road-Stream Crossings

U.S. Department of Transportation
Federal Highway Administration

FOREST SERVICE
U.S.
DEPARTMENT OF AGRICULTURE

U.S.
FISH & WILDLIFE
SERVICE

Stream Simulation: A Simple Example

Stillwell Creek

Finished Project – How did we do it?

Old culvert inlet

New culvert

Phase 1
Initial
Assessment

Phase 2
Site Assessment

Phase 3
Stream Simulation
Design

Phase 4
Final Design &
Contract Preparation

Phase 5
Construction

Phase 6
Maintenance
& Monitoring

Stream
Simulation
Project
Phases

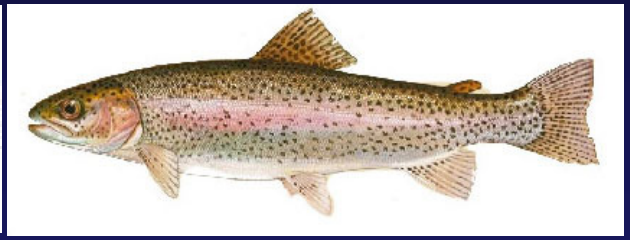
Phase 1 - Initial Assessment

- Primary Resource Objective is
  - to provide access for salmon & coastal cutthroat to 1 mile of valuable rearing and spawning habitat.
  - provide access for other aquatic organisms for aquatic ecosystem restoration.
- Secondary Resource Objective is
  - maintain vehicle access for watershed management

Example of Local Residents and Visitors

Coho salmon

steelhead



Coastal cutthroat trout

Crayfish

Pacific giant salamander

Tailed Frog

sculpin

Initial Assessment of Watershed Characteristics & Risks

- Stability:
  - Geology is weathered sandstone, mudstone and basalt.
  - Landslide and debris torrent prone topography.
  - Periodic input of large conifers and alders.
  - Annual input of colluvium and wood debris

Looking upstream at Wood and sediment

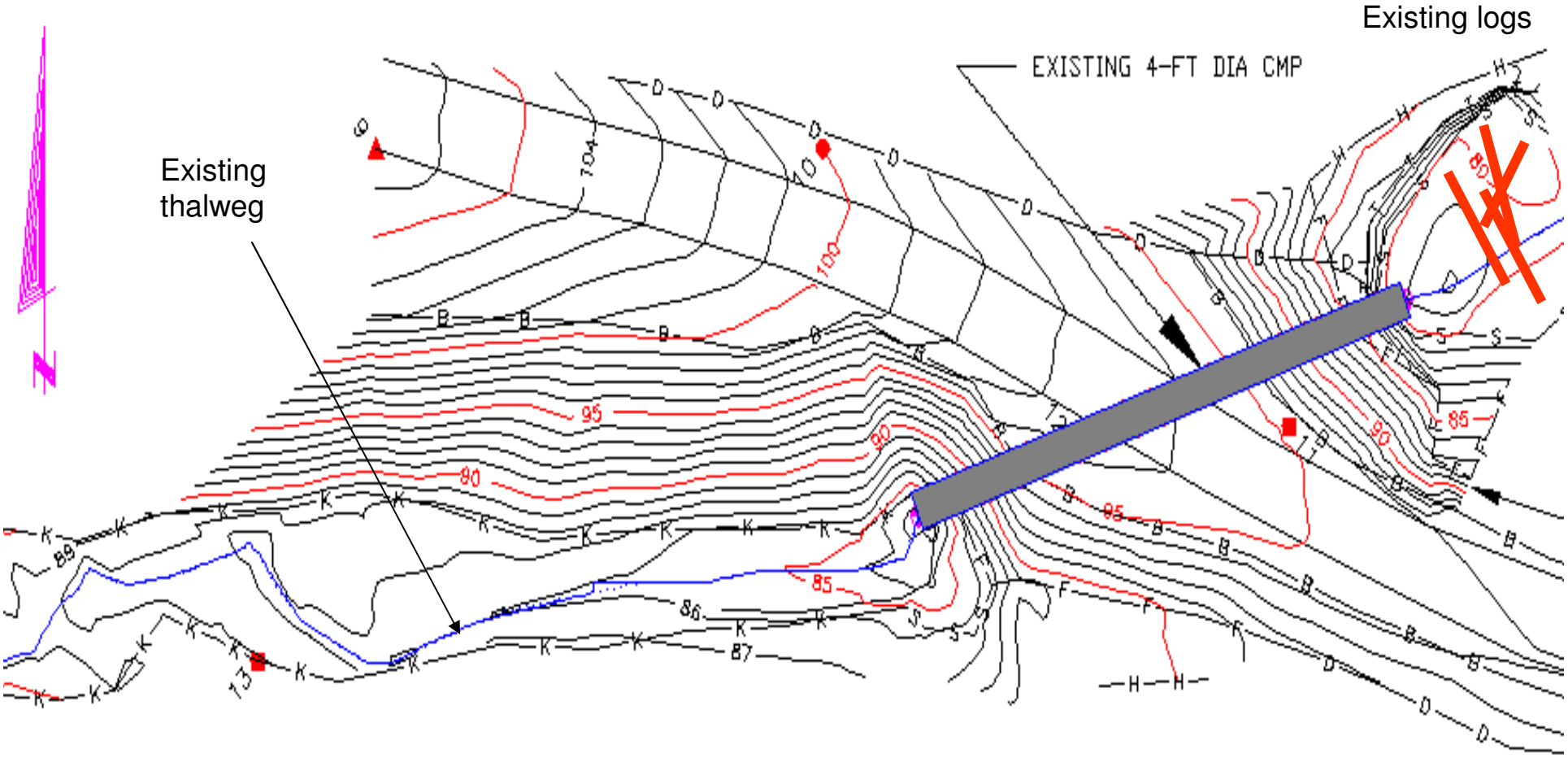
Risk of culvert plugging, road embankment failure, "take"

Phase 2 - Site Assessment

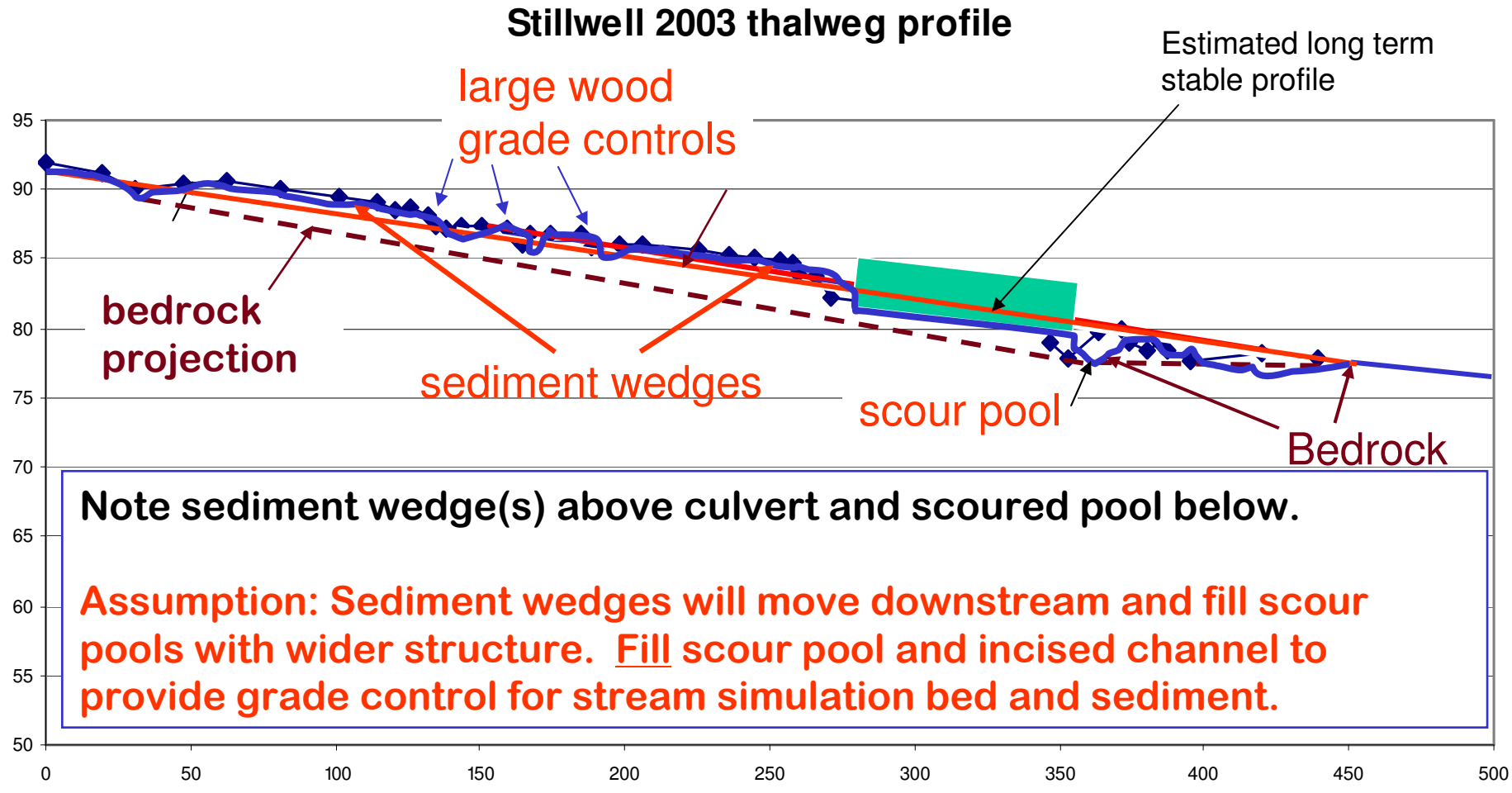
- Develop Plan view sketch map
  - identify bank characteristics, stability, materials
  - geotechnical subsurface investigation
- Obtain survey site plan for stream restoration and structure design
  - Analyze long profile and alignment
  - Determine structure's channel position: grade, elevation, bearing, length
- Analyze and interpret site data
  - Identify a reference reach, channel design template
  - quantify & characterize bed, bank and grade control materials
- Results – understand risks, detailed project objectives

Site Survey

Sharp skew angle, makes for a long structure
Both banks are steep and will control location of new culvert edges



Long Profile



Note sediment wedge(s) above culvert and scoured pool below.

Assumption: Sediment wedges will move downstream and fill scour pools with wider structure. Fill scour pool and incised channel to provide grade control for stream simulation bed and sediment.

Upstream Channel

Aggraded inlet.
Sediment wedge upstream

Upstream Debris torrent deposits & large wood, Periodic bedrock exposure

Downstream Channel

3’ deep outlet pool scoured to bedrock.

Avg. depth to bedrock estimated to be 2 feet by observation & drive probe

Downstream wood grade controls, periodic bedrock exposure

Reference Reach
Analyze and Interpret

- Similar to culvert location
  - gradient (3.8%)
  - Average bank full width (18 feet)
  - bed material sizes
  - soil and alluvium banks
  - Moderately formed step pools of cobbles and wood

Site Suitability Questions

- Given site conditions what structure types are feasible?
  - Is there bedrock within the desired embedment depth?
  - Channel restoration is needed to correct aggraded and scoured pool area.
- What are the long term risks?
  - Debris plugging and fill failure
- Structure Feasibility - yes for all
  - ✓ Bridge - skew?, largest opening
  - ✓ Open bottom arch - good for bedrock
  - ✓ Embedded pipe - 2 ft embedment depth?

Phase 3 –Stream Simulation Design

- Pick the appropriate structure for the site.
  - Determine structure width, length

Use the reference reach information, and identify:

  - Desired stream width inside culvert
  - Desired gradient
  - Type of bedforms inside culvert
  - Embedment depth of culvert

Identify alternative structures

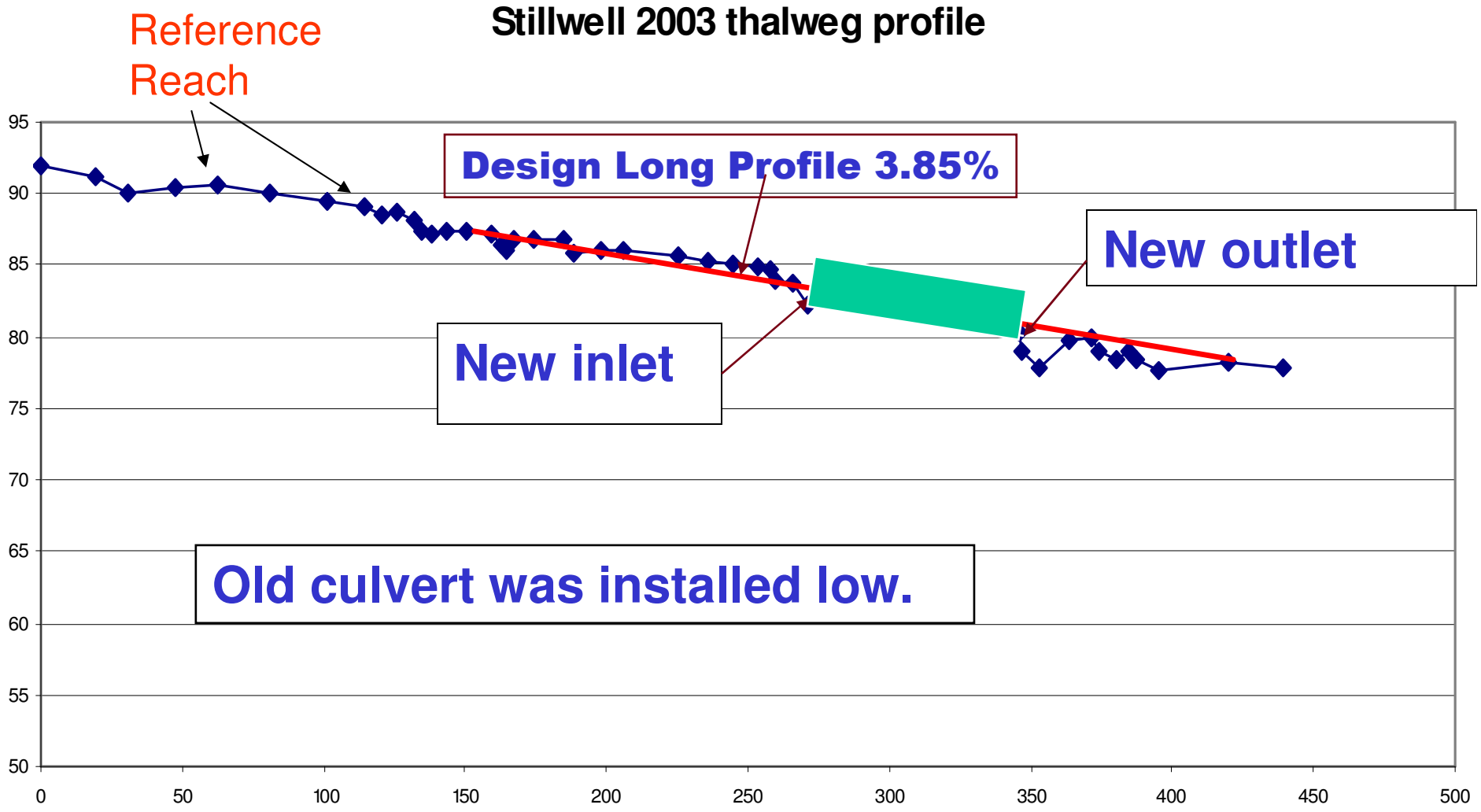
- Results:
  - sketches and descriptions of stream simulation bed and depth for engineering design and contract
- *Document design process & assumptions for contract administration and monitoring purposes*

Stream Simulation Design, Structure Width

- Analyze various structure sizes and shapes that meet design width:
  - Check with FishXing ~ ½ full at Q100
  - Room for debris? ~ mostly, big trees = maintenance
  - How well does it fit? ~ ease of bed construction and stability features.

- Final choice: Choose 18’ x 8’11” open bottom arch
  - Economical shape, large opening, embedment depth
  - With concrete footings formed on bedrock

Long Profile - Checked Against Alignment



Select bedform materials

- Best reference reach in recently deposited sediments.
- Developing steps composed of largest material.
- Construct steps within culvert @ reference reach spacing
- *Important for stream material stability.*

Stream Simulation Design
Select Bed Material Gradations

- Stream simulation materials to give you similar
  - stability
  - permeability
  - Complexity
- "Pebble count" gradation of streambed
  - Is the same as an engineering gradation (% passing & sieve size)
- Construct steps with largest material
  - Individual rocks or graded material

Phase 4 – Final Design and Contract Preparation

- Produce drawings and specifications for:
  - structure and foundation details, bedding
  - roadway,
  - erosion control, dewatering,
  - bypass roads,
  - stockpile sites.
  - and everything else
- Determine quantities and estimate costs
- Develop Contract Documents

- Results: Final design and Contract solicitation package

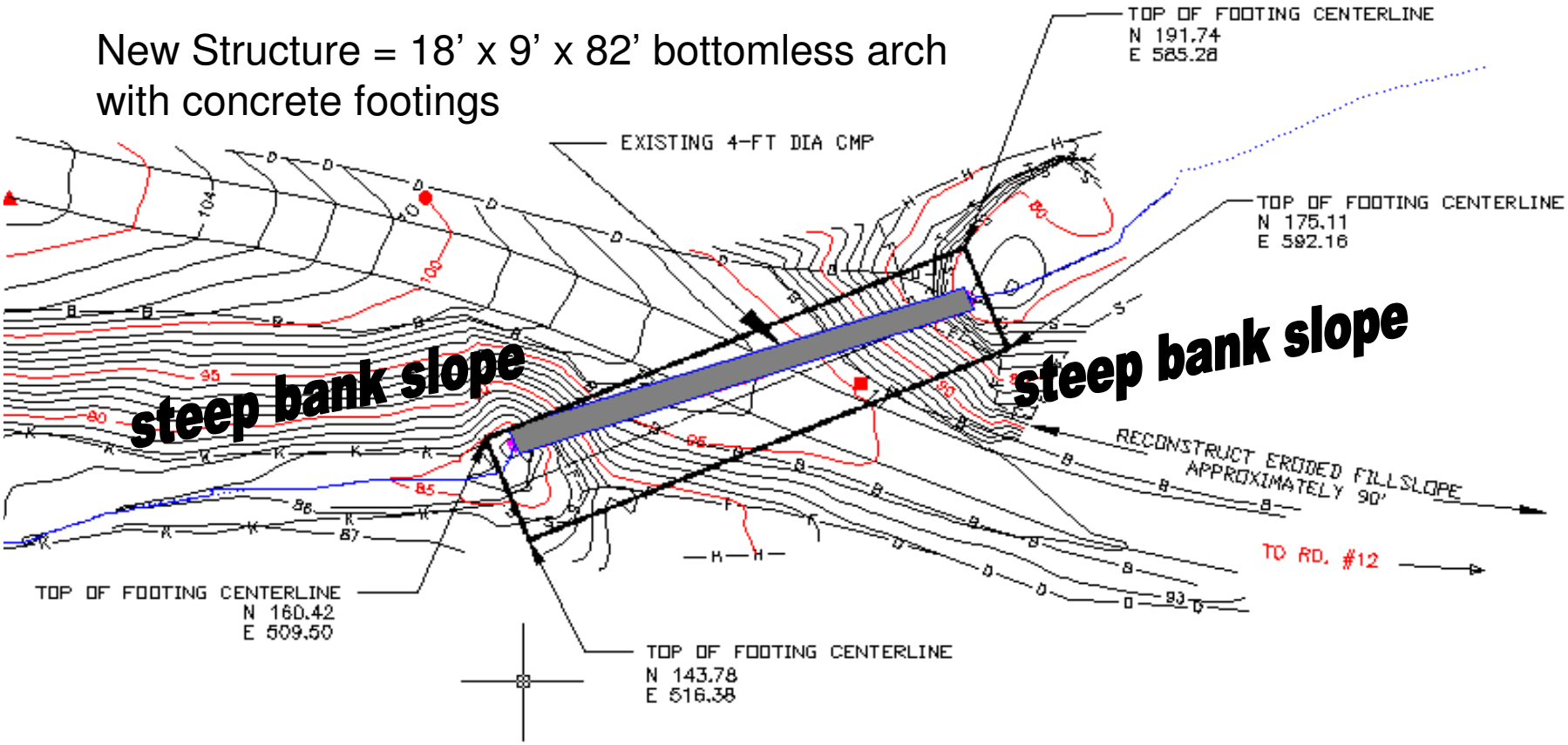
Contract Drawings follow for:

- Site Plan
- Structure Profile
- Structure Cross Section
- Dewatering Plan

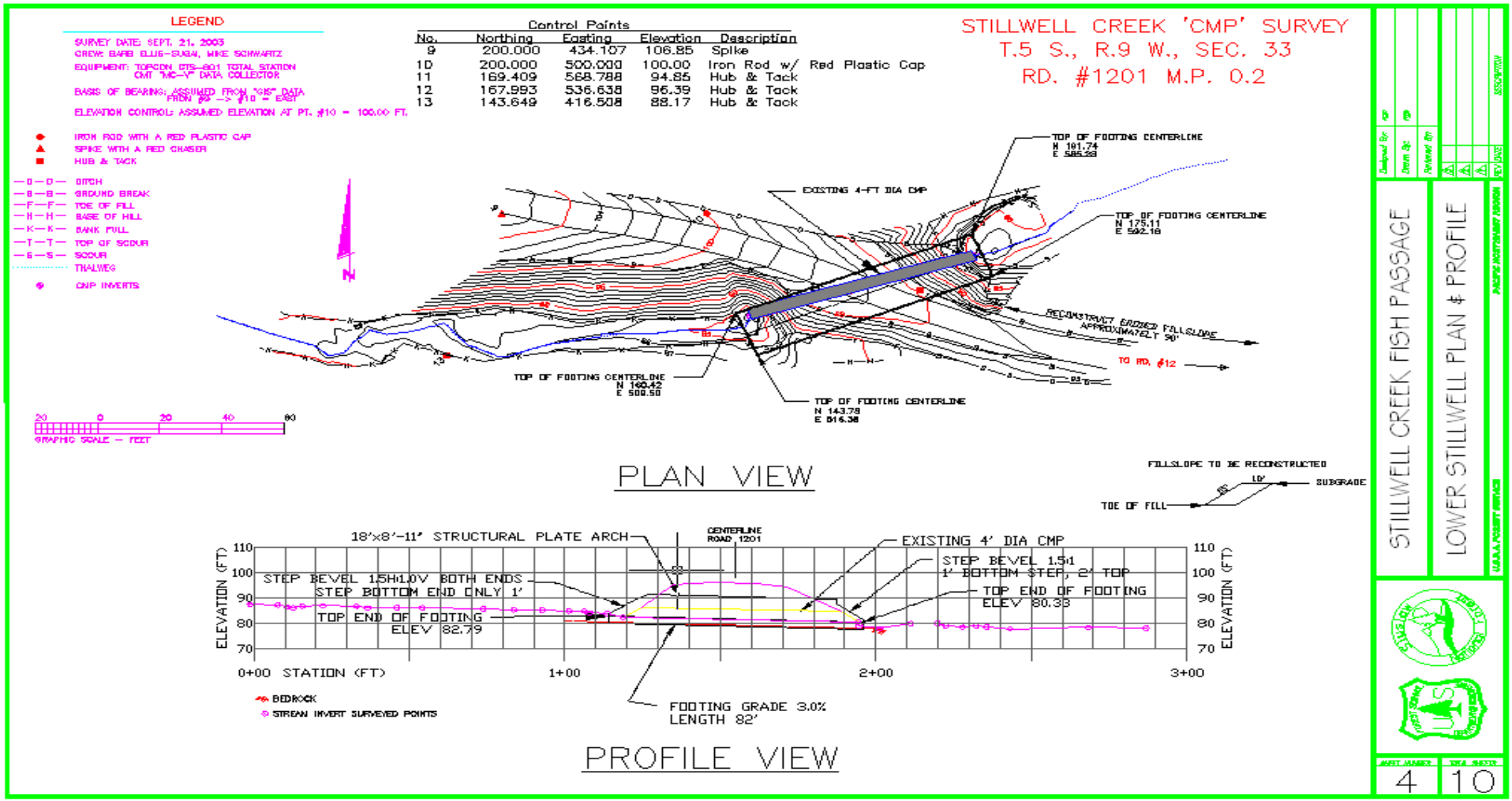
New Structure Alignment

Headwalls considered to reduce length but were too costly for a noticeable improvement.

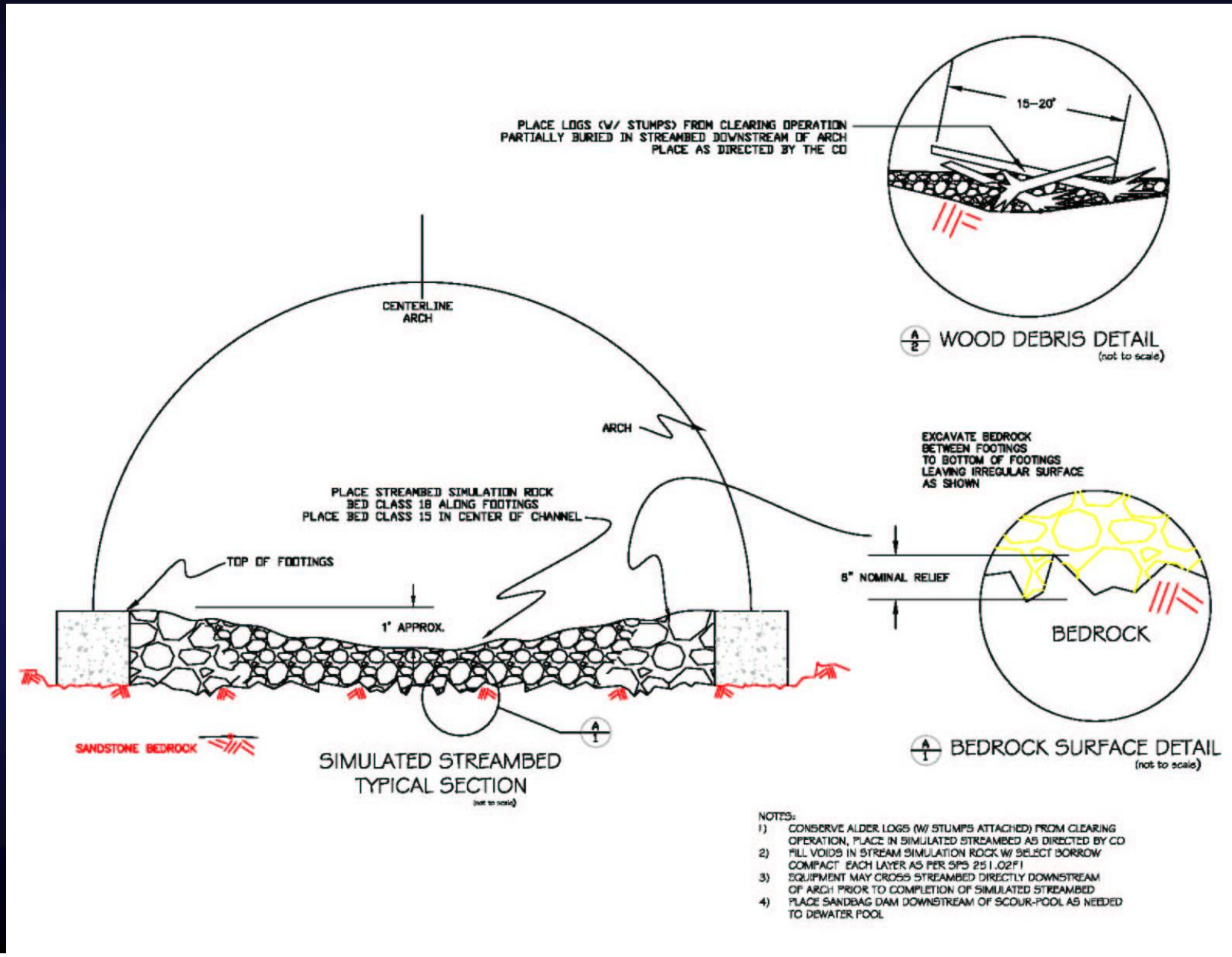
New Structure = 18’ x 9’ x 82’ bottomless arch with concrete footings



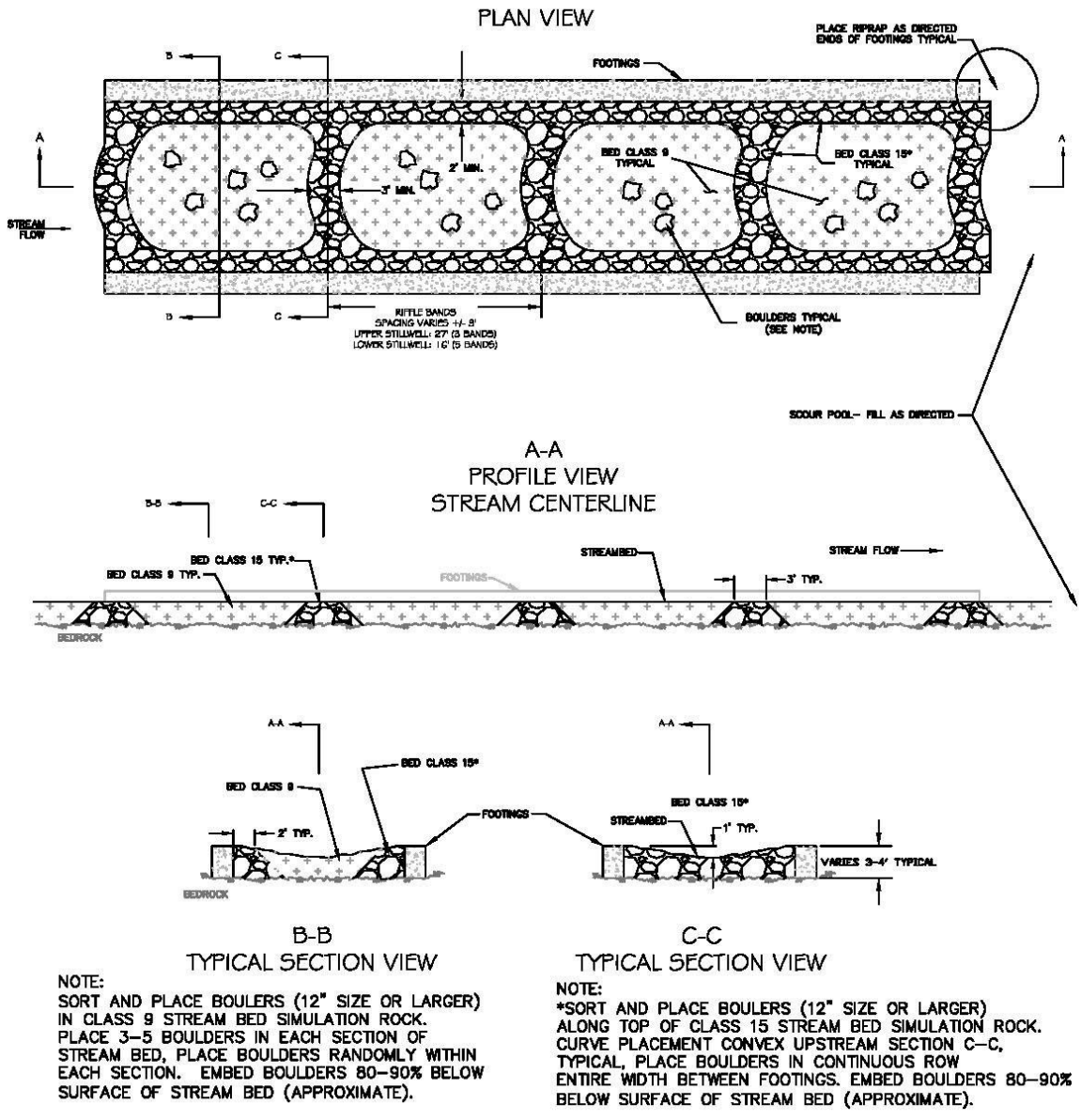
Site Plan, Profile, Survey



Stream Simulation Channel Shape



Stream Channel Structure



B-B
TYPICAL SECTION VIEW

NOTE:
SORT AND PLACE BOULERS (12" SIZE OR LARGER) IN CLASS 9 STREAM BED SIMULATION ROCK. PLACE 3–5 BOULDERS IN EACH SECTION OF STREAM BED, PLACE BOULDERS RANDOMLY WITHIN EACH SECTION. EMBED BOULDERS 80–90% BELOW SURFACE OF STREAM BED (APPROXIMATE).

C-C
TYPICAL SECTION VIEW

NOTE:
*SORT AND PLACE BOULERS (12" SIZE OR LARGER) ALONG TOP OF CLASS 15 STREAM BED SIMULATION ROCK. CURVE PLACEMENT CONVEX UPSTREAM SECTION C–C, TYPICAL, PLACE BOULDERS IN CONTINUOUS ROW ENTIRE WIDTH BETWEEN FOOTINGS. EMBED BOULDERS 80–90% BELOW SURFACE OF STREAM BED (APPROXIMATE).

Phase 5 - Construction

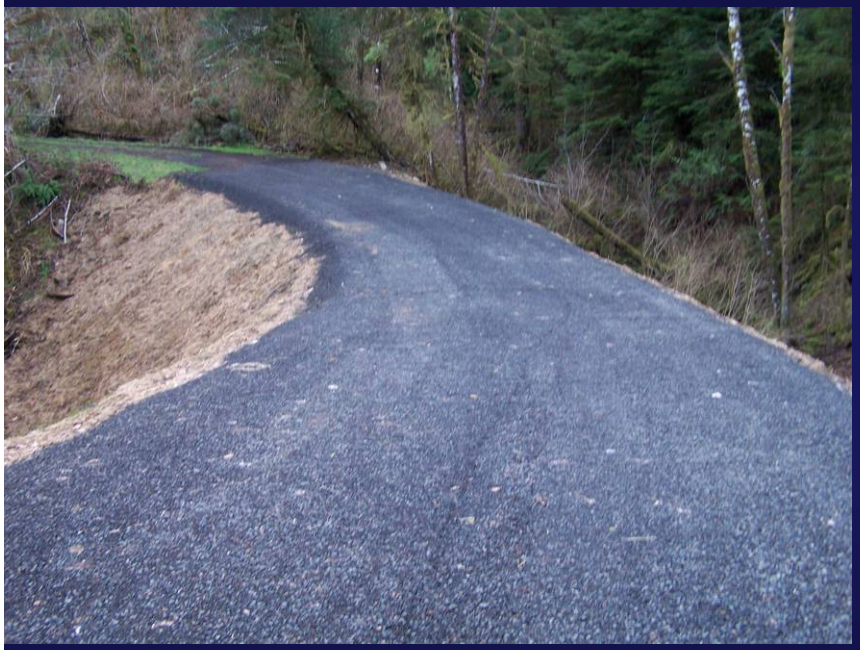
- Inspection and control
- Documentation
- Design changes (minimize)

Phase 5 - Construction

- Footing are constructed, steps built, and stream simulation materials placed
- *Note: the streambed has been diverted into a pipe runs parallel to the footing.*

Structure is assembled and backfilled

Completed Project

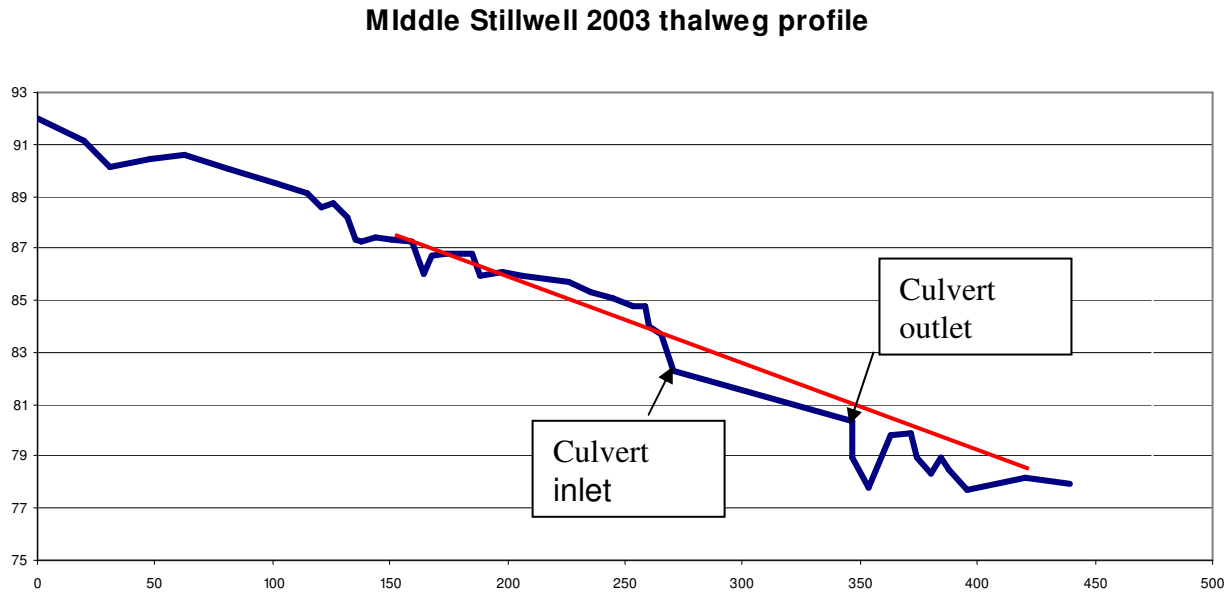


Completed Road Crossing for traffic

Completed Stream Crossing for Aquatic Organisms

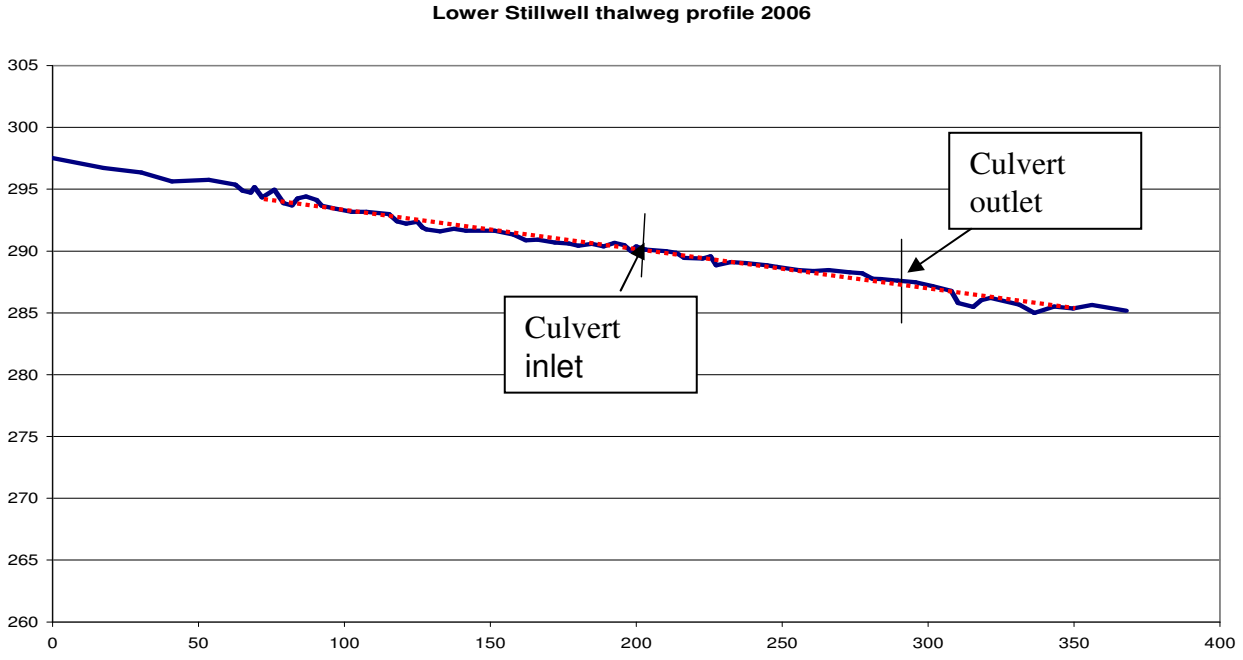
Phase 6 - Post Construction Maintenance and Monitoring

- Monitor - not intensive for this project
  - Biological - monitor # reds developing
  - Structure - settlement, foundation scour
  - Streambed - stability, shape, complexity
  - Site Stability - bank erosion, stability



Prior to replacement.

Note the aggraded sediment wedge above the culvert and the plunge pool below it. Gradient of red line through culvert area is 3.85%.



Thalweg profile April 2006 after 3 winters.

Note the gradient is becoming more uniform along the red line.

Conclusions

- Goals:
  - Passage for aquatic organisms that are present, water (Q100 flow), and sediment.
- Method:
  - Connecting the stream channel above and below the culvert with a similar stream segment through the culvert or bridge.

RESULT:

Barrier to organisms wood and flow achieved, and risk to road greatly reduced.